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Logging Utilization—Colorado, Wyoming, and Western South Dakota

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RESEARCH SUMMARY

Reports results of studies made on timber harvesting operations in Colorado, Wyoming, and western South Dakota to estimate logging residue (the component of slash consisting of growing-stock and sawtimber volume), non-inventory product volume (the component of timber products consisting of material other than growing-stock and sawtimber volume), and removals (the growing-stock and sawtimber volume removed from inventory in logging residue and timber products) associated with harvesting. Results show: factors that can be applied to product volumes to estimate removals, noninventory product volume, logging residue from product trees, and logging residue from nonproduct trees; the number and volume of trees by diameter at breast height class removed from growing-stock inventories per thousand cubic feet of product volume; the volume of residue in pieces 6 feet and longer to a 4-inch top as a proportion of product volume; and board-foot/cubic-foot conversion factors. This report also covers survey methods and data reliability.

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INTRODUCTION

The Forest Survey Unit of the Intermountain Research Station inventoried the non-National Forest lands in Colorado in 1982 and Wyoming and western South Dakota (that part of South Dakota west of the 103d meridian, including the Black Hills) in 1983 to estimate and describe the volume, growth, and mortality of the forests' trees. Timber product output, fuelwood harvest, and logging utilization studies were conducted concurrently with those inventories. The first two studies, timber product output and fuelwood harvest, provided estimates of log volumes harvested and delivered to primary wood processors (such as sawmills and houselog plants) and residences burning wood. The logging utilization studies provided the factors to convert these harvest estimates to estimates of removals associated with harvesting. These removals estimates, when compared to inventory volumes and growth, are used to estimate residual inventories and rates of inventory change associated with harvesting. The factors themselves provide a means to analyze the components of removals and, when compared to those developed in previous years, to ascertain changes in logging utilization practices.

This bulletin reports the results of logging utilization studies conducted in Colorado, Wyoming, and western South Dakota, their use, and the study methods. The report presents factors to apply to harvest estimates to obtain estimates of removals (the growing-stock and sawtimber volume removed from inventory), logging residue (the growing-stock and sawtimber volume of slash), diameter class distributions of the harvests, and the volume of residue in pieces 6 feet and longer.

The bulletin illustrates the factor formulas and the application of the factors and presents the derived estimates of logging residue, noninventory product volume, and removals for the three States.

Cubic-foot/board-foot conversions for both International 1/4-inch and Scribner rules are also included.

STUDY METHODS

Separate studies were conducted for each of the three States using the sampling and measurement techniques designed by A. K. Wilson of the Forest Survey Project at the Intermountain Station in 1959-60.

Sample Size and Distribution

Measurements were obtained on active sawlog and multiproduct logging operations, located on timberland, visited in the summers of 1983 (Colorado) and 1984 (Wyoming and South Dakota). These operations, composing the basic sample units, were distributed throughout the States and were selected within four strata defined by land ownership and operator size class. Two ownership classes were used—National Forest and other. Operator size class corresponded to the production class of the wood processing plant receiving the logs harvested. Two size classes were used—small (less than 10 MM board feet per year) and large (10 MM board feet and more per year).

Sample size was calculated to achieve a standard error of the logging residue ratio (total net cubic foot volume of logging residues divided by the total net volume of timber products) of not more than ±20 percent for each State.

The samples for each State were distributed throughout the strata in proportion to the estimated harvest volume occurring in each stratum. For instance, in Wyoming it was estimated that measurements from 17 logging operations would provide sufficient sample data to achieve a standard error of the ratio of 18 percent. Further, it was estimated that "large" mills (those with capacities of at least 10 MM board feet per year) received about 45 percent of the timber production and that 85 percent of the harvest occurred on National Forests. The 17 samples were distributed as close to these estimates as possible. Measurements were collected on eight logging operations (table 1) sending logs to "large" mills and 15 logging operations on National Forest lands.

Data Collection

The study design prescribed four basic measurements to be obtained from each sample unit to meet the primary objectives of computing removals and logging residue factors.

On each sample unit 10 to 30 felled and bucked product trees (trees felled for timber products) and a varying number of associated nonproduct trees (trees not selected for harvest; see Terminology) were measured to obtain the following:

1. Product volume
2. Noninventory volume in products
3. Volume of logging residue from product trees
4. Volume of logging residue from nonproduct trees

All measured trees were categorized as pole timber, sawtimber, (salvable) dead, cull, or nontimber (from other sources). Both gross (includes defect) and net volumes in cubic feet and board feet (International 1/4-inch rule and Scribner rule) were obtained by scaling. These

Table 1—Number of logging operations within each stratum measured to obtain logging residue data by State, year, and owner group

Stratum	Owner group		
	National Forest	Other	Total
	Number of operations measured		
Colorado, 1983			
Mill size:			
Small	8	3	11
Large	12	2	14
Total	20	5	25
Wyoming, 1984			
Mill size:			
Small	8	1	9
Large	7	1	8
Total	15	2	17
South Dakota, 1984			
Mill size:			
Small	4	1	5
Large	8	1	9
Total	12	2	14

measurements were related to obtain factors (proportions) to apply to reported product volumes received by primary wood processors. Thus, all factors were calculated as proportions of live product volume or live and dead product volume (little product volume from dead trees was encountered on the logging operations measured and no product volume from cull or nontimber species was encountered).

Factor Formulas

$$\text{Logging residue factor} = \frac{\text{product tree residue volume}}{\text{live product volume}} + \frac{\text{nonproduct tree residue volume}}{\text{live + dead product volume}}$$

$$\text{Product tree residue factor} = \frac{\text{product tree residue volume}}{\text{live product volume}}$$

$$\text{Nonproduct tree residue factor} = \frac{\text{nonproduct tree residue volume}}{\text{live + dead product volume}}$$

$$\text{Noninventory product volume factor} = \frac{\text{noninventory product volume}}{\text{live product volume}}$$

$$\text{Inventory product volume factor} = \frac{\text{inventory product volume}}{\text{live product volume}}$$

or

$$\text{Inventory product volume factor} = 1 - \text{noninventory product volume factor}$$

$$\text{Removals factor} = \frac{\text{live product volume} - \text{noninventory product volume} + \text{product tree residue volume}}{\text{live product volume}} + \frac{\text{nonproduct tree residue volume}}{\text{live + dead product volume}}$$

STUDY RESULTS

The factors presented in table 2 were used to derive the growing-stock and sawtimber removals estimates presented in tables 3 through 5.

Sawlog and Other Industrial Estimates

Primary wood processors provided annual estimates of the total sawlog and other industrial timber product volumes received at their plants (McLain 1985, 1987) and estimates of the proportion of that volume cut from dead trees. The volume from dead trees, exhibited in the "Salvable dead" column of tables 3-5, was subtracted from the timber product volume. The appropriate factors in table 2 were applied to the remainder ("Live" column, tables 3-5) to obtain the estimates of product volume from growing stock and sawtimber, the product volume from noninventory material in product trees, and the growing-stock and sawtimber volumes left as logging residue (product tree residue; and nonproduct tree residue resulting from the harvest of live product trees).

Additionally, the nonproduct tree residue factors were applied to the salvable dead product volumes to obtain the growing-stock and sawtimber volumes of nonproduct trees destroyed and killed while logging the salvable dead trees.

Table 2—Logging residue, noninventory product volume, and removals factors in cubic and board feet for Colorado, Wyoming, and western South Dakota

Type of factor	Colorado			Wyoming			South Dakota		
	Cubic	*B.f.S.*[1]	*B.f.I.*[2]	*Cubic*	*B.f.S.*[1]	*B.f.I.*[2]	*Cubic*	*B.f.S.*[1]	*B.f.I.*[2]
Logging residue	0.072	0.022	0.021	0.064	0.016	0.015	0.077	0.015	0.014
Product tree residue	.065	.021	.020	.060	.016	.015	.075	.015	.014
Nonproduct tree residue	.007	.001	.001	.003	0	0	.002	0	0
Noninventory product volume	.005	.036	.038	0	.021	.022	0	.011	.010
Inventory product volume	.995	.964	.962	1	.979	.978	1	.989	.990
Growing-stock (cubic) or sawtimber removals (bd ft)	1.067	.987	.983	1.064	.994	.993	1.077	1.004	1.004

[1]Board feet, Scribner rule.
[2]Board feet, International 1/4-inch rule.

Table 3—Timber production and timber removals for Colorado by source of material and product, 1983

Products and additional removals	Product volume			Other[2] sources	Noninventory product volume	Growing-stock removals
	Total[1]	Live	Salvable dead			
	M cubic feet					
Sawlogs	20,279	18,700	1,579	—	94	18,606
Other industrial	990	944	46	—	5	939
Total[1]	21,269	19,644	1,625	—	99	19,545
Fuelwood	40,375	3,990	29,869	6,516	20	3,970
Logging residue	—	—	—	—	—	1,425
Total[1]	61,644	23,634	31,494	6,516	119	24,940
						Sawtimber removals
	M board feet (Scribner)					
Sawlogs	100,515	92,689	7,826	—	3,337	89,352
Other industrial	2,933	2,783	150	—	99	2,684
Total[1]	103,448	95,472	7,976	—	3,436	92,036
Fuelwood	164,776	19,407	145,283	86	698	18,708
Logging residue	—	—	—	—	—	2,108
Total[1]	268,224	114,879	153,259	86	4,134	112,852
	M board feet (International 1/4-inch)					
Sawlogs	120,084	110,771	9,313	—	4,209	106,562
Other industrial	3,495	3,317	178	—	127	3,190
Total[1]	123,579	114,088	9,491	—	4,336	109,752
Fuelwood	196,824	23,182	173,539	103	881	22,301
Logging residue	—	—	—	—	—	2,405
Total[1]	320,403	137,270	183,030	103	5,217	134,458

[1]Data may not add to totals due to rounding or truncating.
[2]Other sources board-foot volume contains only timber species from nonforest lands. Nontimber species have no board-foot volume.

Table 4—Timber production and timber removals for Wyoming by source of material and product, 1984

Products and additional removals	Product volume				Noninventory product volume	Growing-stock removals
	Total[1]	Live	Salvable dead	Other[2] sources		
	M cubic feet					
Sawlogs	29,496	27,934	1,562	—	—	27,934
Other industrial	522	430	92	—	—	430
Total[1]	30,019	28,364	1,655	—	—	28,363
Fuelwood	10,374	1,137	8,472	766	—	1,137
Logging residue	—	—	—	—	—	1,820
Total[1]	40,393	29,501	10,127	766	—	31,321
						Sawtimber removals
	M board feet (Scribner)					
Sawlogs	146,022	138,287	7,735	—	2,904	135,383
Other industrial	1,076	645	430	—	14	631
Total[1]	147,098	138,932	8,165	—	2,918	136,014
Fuelwood	47,267	5,583	41,640	44	117	5,466
Logging residue	—	—	—	—	—	2,223
Total[1]	194,364	144,515	49,805	44	3,035	143,703
	M board feet (International 1/4-inch)					
Sawlogs	174,496	165,253	9,243	—	3,636	161,617
Other industrial	1,285	771	514	—	17	754
Total[1]	175,781	166,024	9,757	—	3,653	162,371
Fuelwood	56,466	6,675	49,739	52	147	6,528
Logging residue	—	—	—	—	—	2,490
Total[1]	232,247	172,699	59,496	52	3,800	171,389

[1]Data may not add to totals due to rounding or truncating.
[2]Other sources board-foot volume contains only timber species from nonforest lands. Nontimber species have no board-foot volume.

Fuelwood Estimates

Because the logging utilization data were not collected from fuelwood harvesting operations, some adjustments were made to estimate removals from growing stock and sawtimber associated with fuelwood harvesting. Noninventory product volume factors were applied to fuelwood live product estimates, but logging residue factors were not. An assumption was that all the growing-stock volume in trees cut for fuelwood and in trees killed by such logging went into fuelwood (hence, no logging residue), and the fuelwood volume probably contained noninventory volume (magnitude unknown; so, for lack of anything else, we used noninventory volume factors developed from data collected on sawlog and other roundwood harvesting operations).

Use of Factors

The following illustrates the applications of the factors (table 2) to obtain a detailed analysis of noninventory product volume and the components of growing-stock removals for Colorado (M cubic feet; table 3).

Estimate of growing-stock removals:

From products:

Live product volume x inventory product volume factor +
Live fuelwood volume x inventory product volume factor = Total growing-stock removals from products (TGSRP)

Table 5—Timber production and timber removals for western South Dakota by source of material and product, 1983

Products and additional removals	Product volume			Other[2] sources	Noninventory product volume	Growing-stock removals
	Total[1]	Live	Salvable dead			
	M cubic feet					
Sawlogs	22,160	21,931	229	—	—	21,931
Other industrial	951	951	—	—	—	951
Total[1]	23,111	22,883	229	—	—	22,883
Fuelwood	3,363	379	2,626	358	—	379
Logging residue	—	—	—	—	—	1,767
Total[1]	26,474	23,262	2,855	358	—	25,029
						Sawtimber removals
	M board feet (Scribner)					
Sawlogs	115,417	114,226	1,191	—	1,256	112,970
Other industrial	547	547	—	—	6	541
Total[1]	115,964	114,773	1,191	—	1,262	113,511
Fuelwood	15,287	1,929	13,358	—	21	1,908
Logging residue	—	—	—	—	—	1,722
Total[1]	131,251	116,702	14,549	—	1,283	117,141
	M board feet (International 1/4-inch)					
Sawlogs	135,961	134,558	1,403	—	1,346	133,213
Other industrial	644	644	—	—	6	638
Total[1]	136,606	135,203	1,403	—	1,352	133,851
Fuelwood	18,012	2,272	15,740	—	23	2,249
Logging residue	—	—	—	—	—	1,893
Total[1]	154,618	137,475	17,143	—	1,375	137,993

[1]Data may not add to totals due to rounding or truncating.
[2]Other sources board-foot volume contains only timber species from nonforest lands. Nontimber species have no board-foot volume.

From logging residue:

Live product volume x logging residue factor +
Dead product volume x non-product tree residue factor = Total growing-stock removals from logging residues (TGSRLR)

Total removals from growing-stock = TGSRP + TGSRLR

or:

From products:

19,644 x 0.995	=	19,545
3,990 x 0.995	=	3,970
Total TGSRP		23,515

From logging residue:

19,644 x 0.072	=	1,414
1,625 x 0.007	=	11
Total TGSRLR		1,425
Total removals from growing stock	=	24,940

Estimate of noninventory product volume harvested:

Live product volume x noninventory product volume factor +
Live fuelwood volume x noninventory product volume factor =
Noninventory product volume harvested

19,644 x 0.005	=	98
3,990 x 0.005	=	20
Noninventory product volume harvested		118

Alternative

To estimate total removals only, the following procedure could be used:

From products and logging residue (live sawlog and other)
Live product volume x removals factor +

From logging residue (dead sawlog and other)
Dead product volume x nonproduct tree residue factor +

From products (live fuelwood)
Live fuelwood volume x inventory product volume factor = Growing-stock removals

or:

From products and logging residue		
19,644 x 1.067	=	20,960
From logging residue		
1,625 x 0.007	=	11
From products		
3,990 x 0.995	=	3,970
Growing stock removals	=	24,941 (does not equal table 3 due to rounding)

Product Volume From Other Sources

Estimates of product volume cut from nonforest land and nontimber species, labeled "Other sources" in tables 3-5, were obtained in the same manner as the salvable dead estimates. They came directly from the wood processors and fuelwood harvesters, not by application of factors to reported product volumes. Tables 3-5 show that fuelwood was the only product derived in any measurable volume from other sources.

Discussion of Factors

In all three States, the growing-stock (cubic) removals factor exceeds 1 (table 2). This means that residue exceeded noninventory product volume. In most instances, the top logs were bucked short of (below) a 4-inch top diameter outside bark (d.o.b.), often at 7 or 6 inches, or even, less frequently, at 5 inches d.o.b. The wood in the upper stems between the 7-, 6-, or 5-inch top d.o.b. and the 4-inch top d.o.b. is left in the woods as residue. This residue is a removal from inventory, not reflected in product volume.

The sawtimber removals factor is less than 1 in Colorado and Wyoming and only slightly exceeds 1 (1.004) in South Dakota. This is due to the harvest of trees of less than sawtimber size. The resulting board-foot product volume from these trees is not board-foot volume removed from the sawtimber inventory; in other words, it is not sawtimber removals by Forest Survey standards. It is, however, cubic-foot growing-stock removals.

Table 6 exhibits removals factors for the three States from data collected in 1969 (Setzer 1973) compared to that collected in 1983-84. Colorado's current factors are 0.03 and 0.05 less than those of 1969, indicating more noninventory product volume or less residue now than then, or perhaps both. Wyoming's cubic volume factor is about the same as 1969's, while its sawtimber removals factor increased by 0.064. South Dakota's removals factors increased 0.039 (cubic) and 0.02 (board-foot) over 1969's. These increases might reflect a diminished harvest of trees less than sawtimber size (no pulpwood) or decreased utilization of the upper stems, or both.

LOGGING RESIDUE VOLUME IN PIECES 6 FEET AND LONGER

Table 7 contains the cubic volume of product tree residue in sound pieces ≥6 feet in length to a 4-inch top, the factors used to derive the volume estimates, and the proportion of product trees that produced residues ≥6 feet in length to a 4-inch top. The factors were derived from the logging utilization data by dividing the product tree residue volume in pieces ≥6 feet in length to a 4-inch top by the product volume from live trees. The factors are merely the residue volume expressed as a proportion of product volume. Multiplying the factors by the product volume from live timber trees reported by wood processors produces an estimate of residue volume in sound pieces ≥6 feet. Additional residue volume in pieces 6 feet and longer is often available from nonproduct trees damaged or killed by felling or skidding.

The proportion of trees measured that produced residue in pieces 6 feet and longer may be indicative of the degree of utilization; the lower the proportion, the higher the utilization.

Table 6—Removal factors by Forest Survey standards to estimate total net removals from inventory due to logging in Colorado, Wyoming, and western South Dakota, 1983-84 compared to factors computed in 1969

Factor	Colorado			Wyoming			Western South Dakota		
	1969	1983	Diff.	1969	1984	Diff.	1969	1984	Diff.
Growing-stock removals (cubic)	1.100	1.067	(–.033)	1.070	1.064	(–.006)	1.038	1.077	(.039)
Sawtimber removals (bd ft)	1.035	.983	(–.052)	.929	.993	(.064)	.984	1.004	(.020)

Table 7—Volume of, proportion of harvest volume (factor) in, and proportion of product trees containing logging residues to a 4-inch top in pieces 6 feet and longer, Colorado (1983), Wyoming (1984), and South Dakota (1984)

State	Residue volume in pieces 6 feet and longer (MCF)	Factor[1] for residue volume in pieces 6 feet and longer	Proportion of product trees producing residue volume in pieces 6 feet and longer
Colorado	923	0.047	0.420
Wyoming	1,418	.050	.728
South Dakota	1,419	.062	.927

[1]Apply to product volume.

Comparing the proportions from table 7 for 1983 and 1984 to those of 1969 (Setzer 1973), it appears as if the utilization practices in Colorado and South Dakota flip-flopped. The degree of utilization of the product trees is now higher in Colorado than in South Dakota:

	1969	1983-84
Colorado	0.90	0.42
Wyoming	.68	.73
South Dakota	.47	.93

DIAMETER CLASS DISTRIBUTION OF TREES HARVESTED OR DAMAGED

Information on the number of growing-stock trees harvested or destroyed (and, therefore, removed from the inventory) in each diameter class and their associated volumes is useful for computing diameter class cutting rates, which in turn are useful for projecting residual inventory, growth, and yield. Logging utilization data provide an estimate of the distribution of trees removed in relation to the volume of logs harvested. Tables 8-10 present the total number and volume of growing-stock trees (product and nonproduct trees) removed per thousand cubic feet of product volume (excluding fuelwood) from live trees. These diameter distributions, which are statewide averages, may be applied to reported harvest volumes to determine removals by diameter class or be compared to previous years to determine change.

In Colorado, for instance, there appears to be a bulge in the harvest of 8- to 16-inch trees now compared to the 1969 harvest (table 8).

Table 8—Diameter at breast height (d.b.h.) class distribution of the number and volume of growing-stock trees removed from inventory through harvesting per MCF of net product volume, Colorado, 1983—the number of trees removed in 1969 provided for comparison. The 1969 volume by d.b.h. class is unavailable

D.b.h. class	Number of growing-stock trees		Volume of growing-stock trees in cubic feet, 1983
	1969	1983	
2	8.70	2.82	—
4	8.12	3.24	—
6	2.68	1.52	4.75
8	2.75	5.23	47.24
10	2.94	7.58	104.40
12	2.37	7.44	149.58
14	3.32	6.47	161.46
16	2.05	4.06	157.56
18	2.24	2.27	110.25
20	1.53	.90	57.85
22	.77	.48	33.74
24	.77	.83	75.61
26	.70	.83	84.02
28	.45	.41	48.21
30+	.90	.14	12.81
All classes	40.29	44.22	1,067.49

Table 9—Diameter at breast height (d.b.h.) class distribution of the number and volume of growing-stock trees removed from inventory through harvesting per million cubic feet of net product volume, Wyoming, 1984—the number of trees removed in 1969 provided for comparison. The 1969 volume by d.b.h. class is unavailable

D.b.h. class	Number of growing-stock trees		Net volume of growing-stock trees in cubic feet, 1984
	1969	1984	
2	15.32	3.67	—
4	10.97	2.94	—
6	3.65	.94	2.62
8	3.48	4.51	40.94
10	4.70	9.34	133.54
12	7.14	9.03	196.32
14	11.49	5.46	162.20
16	2.61	3.36	143.20
18	2.26	2.20	122.20
20	.87	1.78	143.62
22	.17	.63	61.10
24	.52	.52	59.11
26	.17	—	—
28	.52	—	—
30+	.52	—	—
All classes	64.40	44.41	1,064.88

Table 10—Diameter at breast height (d.b.h.) class distribution of the number and volume of growing-stock trees removed from inventory through harvesting per million cubic feet of net product volume, western South Dakota, 1984 –the number of trees removed in 1969 provided for comparison. The 1969 volume by d.b.h. class is unavailable

D.b.h. class	Number of growing-stock trees		Net volume of growing-stock trees in cubic feet, 1984
	1969	1984	
2	33.29	0.34	—
4	18.59	2.57	—
6	4.39	.67	1.79
8	6.93	2.68	21.35
10	5.41	7.04	98.86
12	6.25	10.17	198.50
14	7.27	6.37	175.48
16	4.73	6.04	222.64
18	3.21	2.91	142.51
20	1.69	1.12	81.70
22	.68	.78	71.53
24	—	.56	61.58
26	—	.11	13.75
28	—	—	—
30+	.17	—	—
All classes	92.61	41.35	1,079.69

Table 11—Product volume conversion factors for Colorado, Wyoming, and western South Dakota

	Colorado	Wyoming	South Dakota	
1 cubic foot equals	4.8625	4.9146	5.0868	board feet (Scribner)
1 cubic foot equals	5.8096	5.8714	5.9944	board feet (International 1/4-inch)
1 board foot equals (Scribner)	1.1948	1.1947	1.1784	board feet (International 1/4-inch)

PRODUCT VOLUME CONVERSIONS

The conversion factors in table 11 were estimated from logging utilization data derived from measurements obtained on the sawlog and multiproduct harvesting operations composing the sample for each State. They are thus State-wide averages, reflecting average conversion for the harvest of the product mix encountered on the samples measured. Caution is recommended in applying these factors to State subdivisions or to harvests of a narrow range of products of small size, such as posts or fuelwood, or sawlogs of exceptionally large diameters (see tables 8-10).

RELIABILITY OF ESTIMATES

The computation of the standard error of the various residues and utilization percentages employs the formula for the standard error of a ratio (Wilson 1965), which may be stated:

$$Sr = \sqrt{\frac{\bar{r}^2}{n}\left[\frac{\Sigma(yi-\bar{y})^2}{(n-1)\bar{y}^2} + \frac{\Sigma(xi-\bar{x})^2}{(n-1)\bar{x}^2} - \frac{2\Sigma(xi-\bar{x})(yi-\bar{y})}{(n-1)\bar{y}\bar{x}}\right]}$$

where

y = logging residues measured on an operation (net volume)

x = timber products measured on an operation (net volume)

$\bar{r} = \frac{\Sigma y}{\Sigma x}$ = logging residues ratio

Table 12—Achieved standard errors of the logging residue volumes/product volume ratios and the standard errors as percentages of the ratios

	Colorado		Wyoming		South Dakota	
	Sr	SE(%)	*Sr*	SE(%)	*Sr*	SE(%)
Cubic foot	0.0086	11.91	0.0080	12.57	0.0113	14.67
Board foot, Scribner	.0044	19.16	.0033	19.68	.0032	21.09
Board foot, international 1/4-inch	.0041	18.81	.0033	20.74	.0030	21.62

n = total number of operations sampled

$$\bar{y} = \frac{\Sigma y}{n}$$

$$\bar{x} = \frac{\Sigma x}{n}$$

$$Sy^2 = \text{variance for } y = \frac{\Sigma(yi - \bar{y})^2}{n-1}$$

$$Sx^2 = \text{variance for } x = \frac{\Sigma(xi - \bar{x})^2}{n-1}$$

$$\text{Cov}(yx) = \text{covariance of } y \text{ and } x = \frac{\Sigma(y - \bar{y})(x - \bar{x})}{n-1}$$

$$Sr^2 = \text{variance for } \bar{r} = \frac{\bar{r}^2}{n}\left[\frac{Sy^2}{\bar{y}} + \frac{Sx^2}{\bar{x}} - \frac{2\,\text{Cov.}(yx)}{\bar{y}\bar{x}}\right]$$

$$Sr = \sqrt{Sr^2} = \text{standard error of the ratio } (\bar{r})$$

$$SE(\%) = \frac{Sr}{\bar{r}} \times 100 = \text{standard error of the ratio as a percentage of the ratio.}$$

Table 12 gives the achieved standard errors of the logging residue volumes/product volumes ratios and the standard errors as percentages of the ratios.

TERMINOLOGY

Cubic-foot/board-foot conversions—The cubic-foot volume in product logs compared to the board-foot volume in the same logs.

Dead product volume—Same as salvable dead volume. The cubic volume in dead poletimber-size and sawtimber-size trees of timber species from a 1-foot stump to a minimum 4-inch top d.o.b. The board-foot volume in dead sawtimber-size trees of timber species between a 1-foot-high stump and a 7-inch d.o.b. top (softwoods) or 9-inch d.o.b. top (hardwoods).

Forest lands—Lands at least 10 percent stocked by forest trees of any size, including lands that formerly had such tree cover and that will be naturally or artificially regenerated. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest trees—Woody plants having a well-developed stem or stems, usually more than 12 feet in height at maturity, with a generally well-defined crown.

Growing-stock product volume—The growing-stock volume in timber products such as sawlogs, posts, poles, pulpwood, fuelwood, and house logs.

Growing-stock removals (in this publication)—The growing-stock volume removed from inventory by harvesting. Consists of logging residue and the growing-stock volume of products.

Growing-stock trees (in this publication)—Live sawtimber trees and poletimber trees meeting specified standards of quality and vigor; excludes cull trees.

Growing-stock volume—Net cubic-foot volume in live poletimber-size and sawtimber-size growing-stock trees from a 1-foot stump to a minimum 4-inch top (of central stem) outside bark or to the point where the central stem breaks into limbs.

Industrial wood products—All timber products except fuelwood.

Inventory product volume—The growing-stock or sawtimber volume in timber products.

Live product volume—Product volume minus salvable dead and other sources.

Logging residue—The unused growing-stock or sawtimber volume of trees cut or killed by logging and left in the woods.

Noninventory product volume—The cubic volume of timber products that came from the upper stems (beyond the 4-inch top d.o.b.) or below the 1-foot-high stumps of growing-stock product trees; the board-foot volume in timber products that came from poletimber trees and below the 1-foot-high stump of sawtimber trees; the product volume of cull trees.

Non-National Forest lands—Lands not administered by the Forest Service, U.S. Department of Agriculture.

Nonproduct tree residue—The growing-stock or sawtimber volume of nonproduct trees cut, killed, or damaged while felling or skidding product trees. This volume is left in the woods. It is a component of slash.

Nonproduct trees—Those trees cut, killed, knocked down, or destroyed due to felling and skidding the product trees.

Other sources—Product volume from nontimber species (such as juniper and, in the West, oak) and trees harvested on nonforest land (such as urban streets, orchards, and windbreaks).

Poletimber trees—Live trees of timber species at least 5 inches diameter at breast height (d.b.h.) but smaller than sawtimber size.

Product tree residue—The unused growing-stock or sawtimber volume of product trees that is left in the woods.

Product trees—Those trees selected for harvest.

Product volume—The cubic-foot or board-foot volume in timber products such as sawlogs, posts, poles, pulpwood, fuelwood, and house logs. Product volume comprises volume from salvable dead trees, other sources, and the noninventory and growing-stock (or sawtimber) volume from growing-stock trees.

Removals—The growing-stock and sawtimber volume removed from the inventory by harvesting. Consists of logging residue and the growing-stock and sawtimber volume of products.

Residual inventory (in this publication)—The growing-stock and sawtimber volume remaining after the inventory is reduced through removals due to harvest.

Salvable dead trees—Standing or down dead trees of timber species that are merchantable by regional standards.

Salvable dead volume—The cubic volume in dead poletimber-size and sawtimber-size trees of timber species from a 1-foot stump to a minimum 4-inch top d.o.b. The board-foot volume in dead sawtimber-size trees of timber species between a 1-foot-high stump and a 7-inch d.o.b. top (softwoods) or 9-inch d.o.b. top (hardwoods).

Sawlog portion—That part of the bole of sawtimber trees between a 1-foot stump and the sawlog top.

Sawlog top—The portion on the bole of sawtimber trees above which a sawlog cannot be produced. The minimum sawlog top is 7 inches d.o.b. for softwoods and 9 inches d.o.b. for hardwoods.

Sawtimber product volume—The sawtimber volume in timber products.

Sawtimber removals (in this publication)—The sawtimber volume removed from inventory by harvesting. Consists of logging residue and the sawtimber volume of products.

Sawtimber trees—Live trees of timber species meeting regional size and defect specifications. Softwood trees must be at least 9 inches d.b.h. and hardwood trees 11 inches d.b.h.

Sawtimber volume—Net volume in board feet of the sawlog portion of live sawtimber trees.

Slash—The wood volume cut or killed as a result of logging and left in the woods (not hauled out as timber products). Slash consists of logging residue (growing-stock and sawtimber volume) and noninventory volume (such as tree tops, limbs, cull trees, dead trees, and nontimber trees).

Timberland—Forest land where timber species make up at least 10 percent stocking.

Timber products—Roundwood products such as sawlogs, posts, poles, pulpwood, fuelwood, veneer logs, and house logs.

Timber removals—Same as "Removals."

Timber species—Trees traditionally used for industrial wood products. In the Rocky Mountains, these include aspen and cottonwood hardwood species and all softwood species except pinyon and juniper.

Total removals (associated with harvesting)—Comprises the growing-stock (or sawtimber) volume contained in products, the product tree logging residue, and the nonproduct tree logging residue.

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McLain, William H. 1988. Logging utilization—Colorado, Wyoming, and western South Dakota. Resour. Bull. INT-52. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 10 p.

Reports results of studies made of timber harvesting operations in Colorado, Wyoming, and western South Dakota to derive factors used to estimate logging residue, growing stock and sawtimber removals, diameter class distribution of harvests, and board-foot/cubic-foot conversions.

KEYWORDS: timber removals, growing-stock removals, sawtimber removals, cubic/board-foot conversions, logging residue

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